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INT CL^5 H04B 7/005
ONLINE DATABASES : WPI

(54) **Improvements in or relating to cellular mobile radio systems**

(57) A CDMA cellular mobile radio system uses time division duplex transmission so that the same carrier frequency is used in both directions of communication. Transmission power at a mobile unit as determined predictively independence upon a succession of received signals. Accurate channel measurement and transmission power control are achieved because of path reciprocity at equal frequencies.

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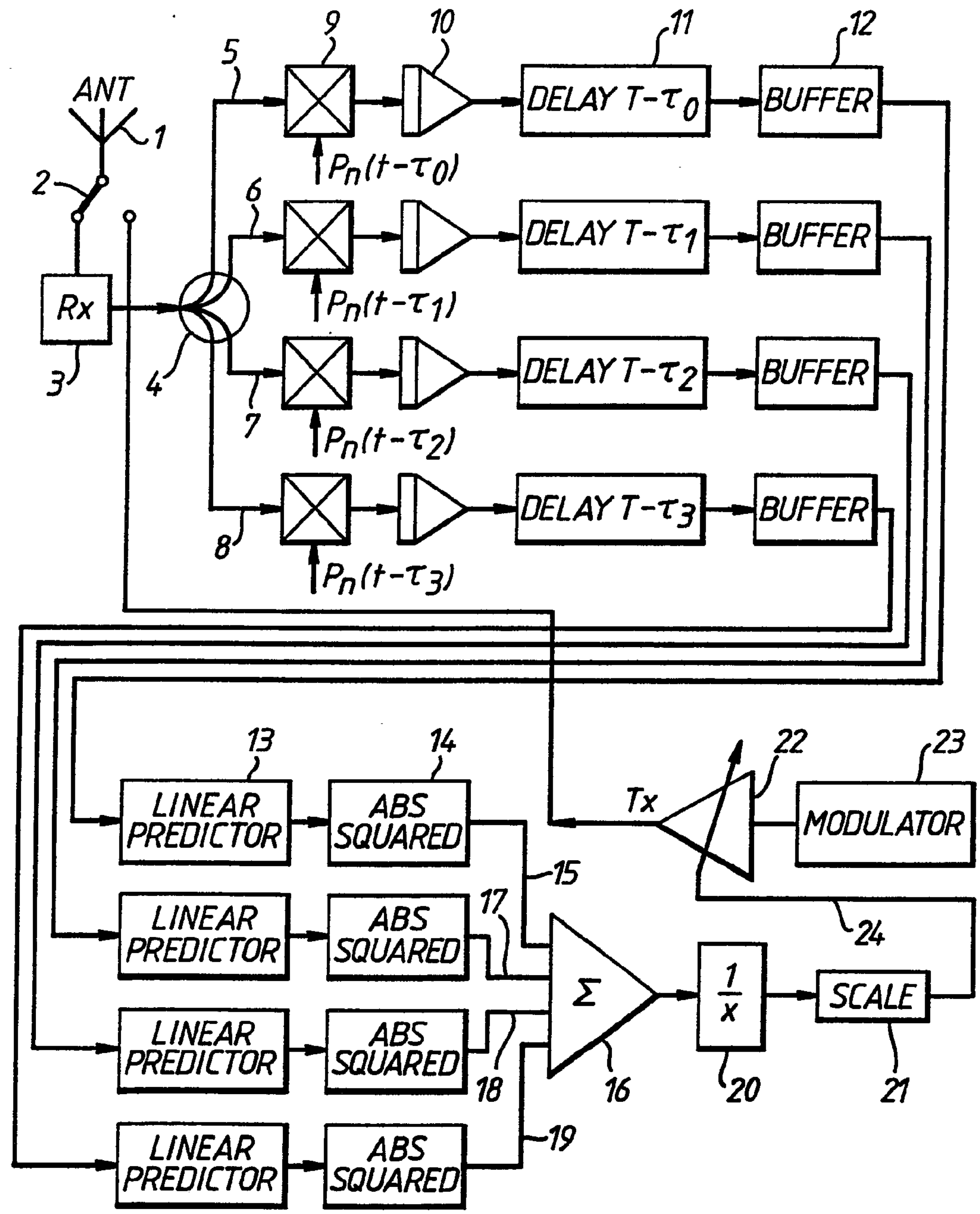
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.


ANT
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2
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3
4
5
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7
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9
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$P_n(t-\tau_3)$
DELAY $T-\tau_0$
DELAY $T-\tau_1$
DELAY $T-\tau_2$
DELAY $T-\tau_3$
11
12
BUFFER
BUFFER
BUFFER
BUFFER
13
14
LINEAR PREDICTOR
ABS SQUARED
LINEAR PREDICTOR
ABS SQUARED
LINEAR PREDICTOR
ABS SQUARED
LINEAR PREDICTOR
ABS SQUARED
15
17
18
19
Σ
16
$\frac{1}{x}$
20
SCALE
21
Tx
22
23
MODULATOR
24

Fig. 1

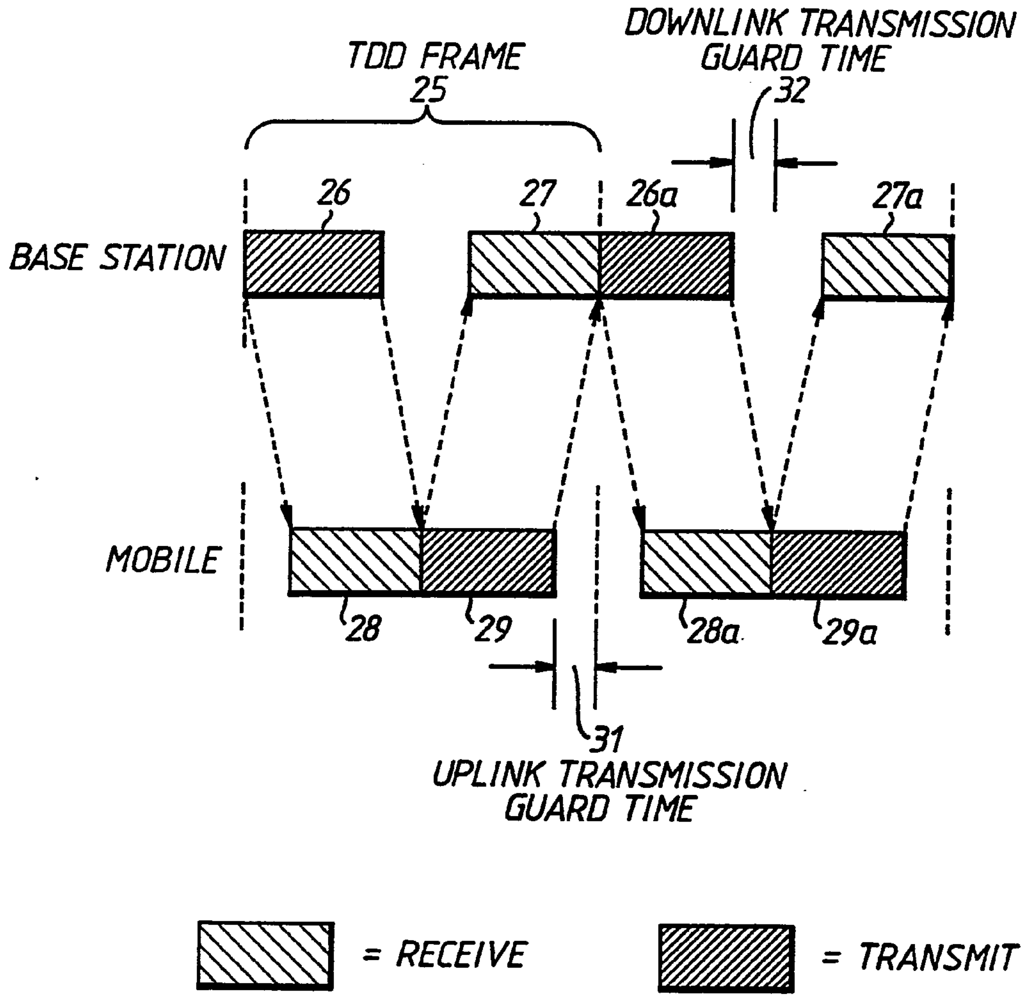
DOWNLINK TRANSMISSION
GUARD TIME
32
TDD FRAME
25
26
27
26a
27a
BASE STATION
MOBILE
28
29
28a
29a
31
UPLINK TRANSMISSION
GUARD TIME
= RECEIVE
= TRANSMIT

Fig.2

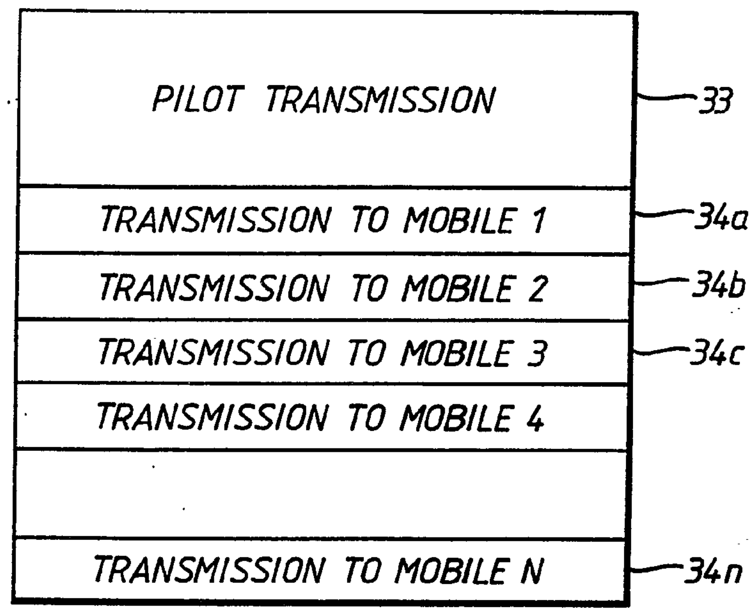
PILOT TRANSMISSION
33
TRANSMISSION TO MOBILE 1
34a
TRANSMISSION TO MOBILE 2
34b
TRANSMISSION TO MOBILE 3
34c
TRANSMISSION TO MOBILE 4
TRANSMISSION TO MOBILE N
34n

Fig. 3

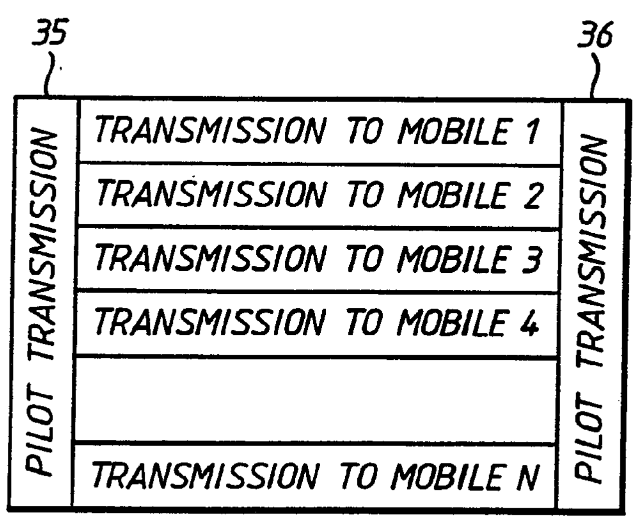
35
36
PILOT TRANSMISSION
TRANSMISSION TO MOBILE 1
TRANSMISSION TO MOBILE 2
TRANSMISSION TO MOBILE 3
TRANSMISSION TO MOBILE 4
TRANSMISSION TO MOBILE N
PILOT TRANSMISSION

Fig. 4

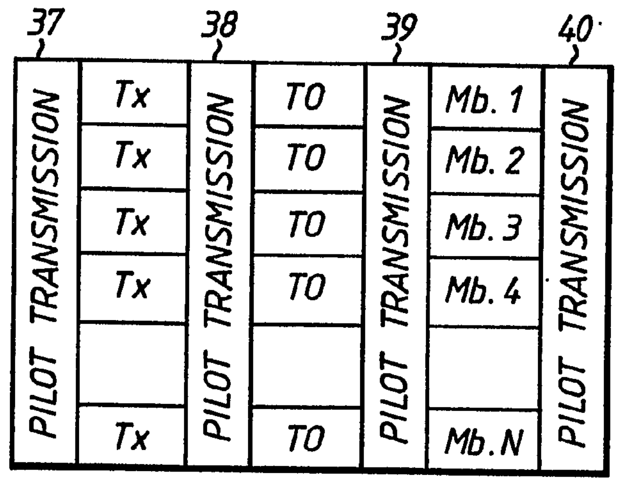
37
38
39
40
PILOT TRANSMISSION
Tx
Tx
Tx
Tx
Tx
PILOT TRANSMISSION
TO
TO
TO
TO
TO
PILOT TRANSMISSION
Mb. 1
Mb. 2
Mb. 3
Mb. 4
Mb. N
PILOT TRANSMISSION

Fig.5

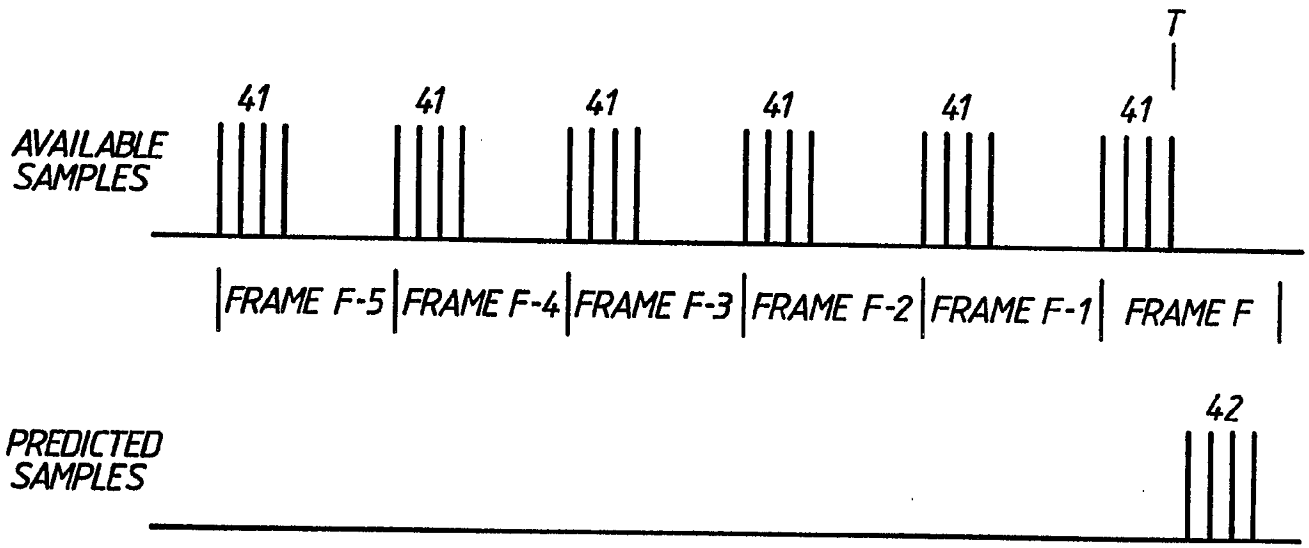
AVAILABLE SAMPLES
41
41
41
41
41
41
T
FRAME F-5
FRAME F-4
FRAME F-3
FRAME F-2
FRAME F-1
FRAME F
PREDICTED SAMPLES
42

Fig.6

IMPROVEMENTS IN OR RELATING TO CELLULAR MOBILE RADIO SYSTEMS

This invention relates to code division multiple access (CDMA) in cellular mobile radio systems.

CDMA cellular mobile radio is normally based on direct sequence spread spectrum (DSSS) and is subject to the so called "near far" problem wherein mobiles closest to a base station cause interference which cannot adequately be suppressed by the spread spectrum processing gain. In general the maximum capacity is achieved only when the power received from all mobiles in a cell is identical. Whilst systems can be designed which substantially achieve this, it is difficult to achieve power control which will track multipath fading, particularly for large doppler spreads (i.e. high vehicle speeds using high frequencies). Two known systems currently used, are (a) Open loop and (b) closed loop.

In an open loop system, the power in a 'down link' (i.e. base to mobile) transmission is measured in order to obtain an estimate of the path loss between the base station and mobile. 'Down link' and 'up link' transmissions normally take place on different frequencies in known systems so that from the viewpoint of multipath, the 'down link' measurement provides a very poor estimate of 'up link' parameters. Thus, open loop control of this kind will only handle slower fluctuations as might arise due to shadowing etc.

In a closed loop system, a base station measures the power of the signal received from a mobile and generates a feedback signal which is transmitted over a 'down link' path to control the mobile's

power towards a demand threshold. This can be quite effective but is limited in tracking capability because of the following factors. One limiting factor is the round trip propagation delay which adversely affects feedback loop dynamics and response time. Another limiting factor is that the accuracy of control within the loop depends upon accurate measurement of the received signal at a base station. Since the purpose of power control is to maintain a received signal at the base station as close to a minimum acceptable level as possible, the signal to noise interference will always be low. This implies that significant time averaging will be required to obtain an accurate measurement of the received signal level. This also appears within the feedback loop, adversely affecting its dynamics and response time.

It is the object of the present invention to provide a gain control system for obviating or at least improving problems associated with the "far near" effect, wherein the aforementioned disadvantages are minimised or obviated.

According to the present invention a CDMA cellular mobile radio system, comprises a plurality of mobile units each arranged to communicate with a base station using a time division duplex (TDD) transmission system such that the same nominal carrier frequency is used for the 'up link' (mobile to base) as the 'down link' (base to mobile), transmission power in the 'up link' being determined predictively in dependence upon successive signals received from the base station in the 'down link'.

By using TDD whereby the same frequency is used in the 'up link' as the 'down link' common multipath characteristics are

experienced in both links which makes measurement of received 'down link' power valid for setting the 'up link' transmission power, and by controlling power in the 'up link' predictively in dependence upon successive signals received in the 'down link', multipath fading effects can be anticipated and appropriately compensated for by controlling power in the 'up link' whereby communication is maintained with a minimum of 'up link' transmission power so that "near far" problems are minimised.

It will be appreciated that although the use of TDD provides correlation between the 'up link' and 'down link' transmission parameters relating to multipath because the same transmit frequency is used, whereby the measurement of 'down link' receive transmission power is valid for the setting of the 'up link' transmission power, except for very short TDD frames, the path loss applying on the 'down link' will very rapidly become decorrelated with that applying on the 'up link' if rapid fading is experienced. The use of very short TDD frames is however, undesirable because of the increasing significance of round trip propagation delays, base station synchronisation errors, and limitations appertaining to data training sequences required. Although, accurate power control using TDD alone is virtually impossible for all but very low vehicle speed, if a prediction function is used to extrapolate the trend of path loss fluctuations on the basis of previous measurements during a current frame, power control errors are minimised whereby the provision of an acceptable system is facilitated.

A wide variety of prediction algorithms may be used with varying levels of complexity and corresponding varying degrees of effectiveness.

A simple prediction algorithm would be to use a linear extrapolation of received power expressed in decibels. In this way the trend of power variation would be extrapolated crudely over the next period. More powerful techniques however, may be used which might involve examination of the individual complex path fluctuations and application of standard linear prediction theory (e.g. a Wiener filter) which is well known to those skilled in the art.

One embodiment of the invention will now be described solely by way of example with reference to the accompanying drawings, in which;

FIGURE 1 is a generally schematic block diagram of a rake receiver modified to incorporate a linear prediction system;

FIGURE 2 is a block diagram illustrating the structure of a TDD frame;

FIGURE 3 is a block diagram showing one base station transmission format using a continuous pilot signal;

FIGURE 4 is a alternative base station transmission format using pulsed pilot signal;

FIGURE 5 is a schematic diagram of another base station transmission format using multiple pulsed pilot signals; and

FIGURE 6 is a diagram illustrating sample selection with the base station transmission format as shown in Figure 5, for predicting channel fluctuations.

Referring now to Figure 1, a mobile unit comprises a transmit/receive antenna 1, which is fed via a two position function switch 2 having a receive mode position and a transmit mode position. In the receive mode, the function switch 2 is arranged to couple the antenna 1 to a receiver 3 which feeds a signal splitter 4. The signal splitter 4 serves to spit the received signal into four paths 5, 6, 7 and 8. The apparatus in each path is similar and so the apparatus in the path 5 only will be described herein. The path 5 comprises a mixer 9, an amplifier 10, a delay unit 11, a buffer 12, a linear predictor 13, and a signal squarer 14, an output signal from the squarer 14 being fed on a line 15 to a signal combiner 16. In a similar manner the paths 6, 7 and 8 provide output signals on lines 17, 18 and 19 for the signal combiner 16. In the paths 5, 6, 7 and 8 the apparatus corresponding to the mixer 9, the amplifier 10 and the delay device 11, defines a well known rake receiver, the mixing and delay function being chosen such that signals produced from the delay units associated with the paths 5, 6, 7 and 8 will combine additively to produce a single output signal from four multipath signals. The use of rake receivers to effect multipath diversity are well known and will not be described in detail herein, suffice it to say that the delay function afforded by the delay devices such as the delay device 11, and the mixing function afforded by the mixer such as the mixer 9 are chosen such that the multipath components of the signal will combine additively. Signals from the delay devices such as the delay device 11 are fed to the buffers such as the buffer 12, wherein successive signal samples from a base station, not shown, are stored. In each case the signals are fed to a linear predictor such

as the predictor 13, squared by the squaring device 14 and fed via the lines 15, 17, 18 and 19 to the summation device 16. An output signal from the summation device 16 is fed via a reciprocal network 20 and a scaling device 21 to a variable gain amplifier 22 which is fed from a modulator 23 and serves to provide a signal for transmission which is supplied to the antenna 1 via the switch 2 when set to the transmit mode position.

In operation of the predictive power control system just before described with reference to Figure 1, signal samples received from a remote base station are stored in the buffers such as the buffer 12, and used by the linear predictors such as the predictor 13, in association with the squaring device 14, to produce a signal from the scaler 21 on a line 24 whereby the gain of the transmission amplifier 22 is controlled in order to minimise or obviate the "near far" effect, as hereinbefore described.

Referring now to Figure 2, as will be appreciated by those familiar with the art, that a single TDD frame 25 comprises a base station transmission frame 26 which is time spaced from a base station receive frame 27. In the same TDD frame a mobile unit in communication with the base station exploits a receive frame 28 followed by a transmit frame 29. The next successive TDD frame similarly comprises a base station transmit frame 26a, a base station receive frame 27a, and a mobile receive frame 28a and a mobile transmit frame 29a. Following the mobile transmit frame 29 an 'up link' transmission guard time 31 is provided, and following the base station transmission 26a, for example, a 'down link' transmission guard time 32 is provided.

In order to facilitate predictive power control as just before described with reference to Figure 1, a base station format may be provided as shown in Figure 3, wherein a pilot transmission 33 is transmitted continuously during transmissions 34a to 34n, which are transmitted contemporaneously and distinguished by direct sequence spread spectrum (DSSS). The pilot transmission is on the same frequency as the mobile transmission and used for predictive power control purposes as described with reference to Figure 1. Samples would be stored in the buffers, such as the buffer 12.

In an alternative base station transmission format, as shown in Figure 4, base station transmission includes pilot transmissions 35 and 36 which follow the data transmissions to mobile units and which as described with reference to Figure 3 are distinguished by direct sequence spread spectrum techniques.

In yet another base station transmission format, as shown in Figure 5, multiple pulsed pilot signals 37, 38, 39 and 40 may be transmitted which are interleaved with signals transmitted to a plurality of mobiles as shown in Figure 5 and distinguished as appropriate by means of DSSS. In this case, as shown in Figure 5, the pilot is becoming a significant factor. Essentially the prediction function takes the samples of the received pilot signals from the base station and uses these to predict path fluctuations over the following transmission.

In the block diagram shown in Figure 1, there are four sets of samples and four prediction functions corresponding to four significant multipath components. As hereinbefore explained the prediction function may take any standard form, e.g. Wiener, but

must be optimised for the noisiness of the samples obtained. Thus, as shown in Figure 6, a number of available samples may be taken in successive frames and used to produce predicted samples in dependence upon which the gain of the amplifier 22 is set to control the transmission amplitude from the mobile. Having obtained the prediction of the expected channel fluctuation during the next successive transmission period, the mobile transmitter power is thus set to follow the inverse of these fluctuations in order to provide a substantially constant signal level at the base station. As will be very well understood by those skilled in the art, this is important because it minimises the interference to other CDMA users, substantially removes wanted signal fluctuations so as further to reduce CDMA interference and minimises or removes fading fluctuations so that the need for long interleaving associated with error control coding is minimised, and thereby the overall transmission delay is reduced. This is very important for time critical services such as speech.

CLAIMS:

1. A CDMA cellular mobile radio system comprising a plurality of mobile units each arranged to communicate with a base station using a time division duplex (TDD) transmission system such that the same nominal carrier frequency is used for the 'up link' (mobile to base) and the 'down link' (base to mobile), transmission power in the 'up link' being determined predictively in dependence upon successive signals received from the base station in the 'down link'.

2. A radio system as claimed in claim 1, wherein each mobile unit comprises a multipath rake receiver, a store for each path of the rake receiver into which sample data appertaining to successively received signals in each TDD frame are stored, predictor means operative in dependence upon the stored signals for predicting the amplitude of the next successive signal and signal control means operative to control the 'up link' transmission power in dependence upon the predictions.

3. A system as claimed in claim 2, wherein the predictor performs a linear prediction function.

4. A system as claimed in claim 1 and substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
GB 9213611.8

Relevant Technical fields

(i) UK Cl (Edition K) H4L (LDSF, LDSX, LECX, LETXX)

(ii) Int Cl (Edition 5) H04B 7/005

Search Examiner
N W HALL

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Date of Search
28 SEPTEMBER 1992

Documents considered relevant following a search in respect of claims 1 TO 4

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	WO 91/07037 A1 (QUALCOMM) whole document	1-4
A	EP 0462952 A1 (BRICSSON) whole document	1-4

Category	Identity of document and relevant passages	Relev—t to cla ,s)

Categories of documents

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Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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